BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Radiation Film Fogging in Earth-Orbital Space Stations Case 730

DATE: November 27, 1967

FROM: C. P. Witze

ABSTRACT

The space radiation levels experienced by an earth-orbiting astronomical observatory were calculated for two near-earth-orbits and an earth-synchronous orbit. Comparison of the obtained radiation levels with the experimentally determined radiation tolerance levels of typical photographic films showed that the fast films used in stellar and galactic astronomy are especially sensitive to fogging from space radiation. It was concluded that a modest shielding requirement in conjunction with expected developments in radiation resistant films offers a more practical and economical solution to the film fogging problem than frequent film replacement.

(NASA-CR-92821) RADIATION FILM FOGGING IN EARTH-ORBITAL SPACE STATIONS (Bellcomm, Inc.) 13 p

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MEMORANDUM FOR FILE

Many experiments on board earth orbiting space stations will use photographic film to register data. It is well-known that high energy radiation in sufficient doses has a deleterious effect upon the quality of photographic images. The purpose of this memorandum is to investigate the magnitude of this problem for a typical earth-orbiting astronomical observatory in order to establish the general character of shielding and/or logistics requirements for keeping available sufficient quantities of high quality film.

SPACE RADIATION LEVELS

In Figures 1, 2, and 3, the approximate radiation levels (rads tissue) to be expected during a one-year mission in the 1970's for circular 250 nm (30°, 90° inclination) orbits and an earth-synchronous (30° inclination) orbit are shown as a function of shield thickness. The electron (projected 1968) and proton integrated orbital trace data was taken from Vette[1], the solar flare dose was based upon the occurrence of major events of the July 1959 type (time of solar maximum), and the galactic cosmic ray dose was obtained from Hilberg[2] for a time of solar minimum. Interesting characteristics of these orbits are (1) the magnetic field of the earth serves as an effective shield from solar and galactic cosmic rays at low orbital altitudes and inclinations, (2) trapped Van Allen protons are the main problem at low altitudes while electrons and cosmic rays are the main problem at synchronous altitudes, (3) decreasing the inclination angle for the 250 nm orbit to 10° reduces radiation levels almost two orders of magnitude because of the avoidance of the "South Atlantic Anomaly" (point of closest approach of the Van Allen belts to the earth's surface), (4) decreasing orbital altitude to 150 nm reduces radiation levels almost one order of magnitude, (5) dose rates encountered while passing through the Van Allen belts to synchronous orbit depends on the trajectory chosen--acceptable translunar trajectories can, for example, vary from a few millirads to a few rads accumulated dose depending on on the insertion parameters[2], (6) dose rates are sufficiently great so as to endanger man as well as film.

PHOTOGRAPHIC FILM FOGGING

The principal use of photographic film aboard the space station would be for purposes of photographing distant stars and galaxies which cannot be resolved from terrestial observatories because of the earth's intervening atmosphere. In such cases, one is generally looking for images on the very edge of detectability on the photographic film. Other possible uses for film are wide and narrow band spectrography and high resolution photographs of planets.

Fogging and granularity are the two effects that radiation can have upon the film. A characteristic of any film is a density (darkening of the film) versus exposure (light intensity X time) curve (H-D curve). An H-D curve for a typical "fast" film that might be used on such a mission is shown in Figure 4. It is seen that (1) the film has a natural background (low exposure) fogging level of about 0.1 and (2) the central portion of the curve is best for photography because it offers the greatest density change for a given exposure. A "slow" film, characterized by smaller grain size and consequent higher resolution than fast film, has its H-D curve shifted to the right by three or four orders of magnitude. Consequently, fast films are generally used in astronomy to record dim images without committing the camera to long exposure times. If the lighting is bright enough such as on the moon or a planet, slow film can be used (Lunar Orbiter, ATM).

The effect of radiation film fogging is essentially to raise the natural background level on the film, thereby decreasing the available exposure with which to obtain sufficient contrast with respect to the background. The slope of the H-D curve is also decreased. These effects are shown qualitatively in Figure 4. The effect of radiation on granularity is to increase grain size thereby decreasing resolution. Careful film processing can some times lessen the effect of film fogging, especially if it is uniform.

Very recent data for the effect of high energy proton bombardment[3] on typical photographic films is illustrated in Table 1. Slow films are seen to be generally the most radiation resistant.

The radiation levels in this experiment were measured in rads air--an equal dose in rads tissue requires an incident proton flux about 12% higher in air than in tissue. The range of 50, 90, and 130 Mev protons in aluminum is 2.9, 8.3, and 15.8 gr/cm^2, respectively.

Comparison of Table 1 with Figures 1-3 show that film fogging will certainly be a problem--even for a 250 nm, 30° inclination orbit with 10 gr/cm^2-Al shielding (representative film location in ATM), some of the more sensitive films may only have a shelf life of 30 days, whereas slower films may be good for up to one year. In synchronous orbit, space radiation levels are about 40% higher. It is a very subjective determination, of course, on how much background fogging density can be tolerated--GSFC has specified that 0.2 fogging density is the maximum that can be tolerated in film type 103-0 for the ATM program[4]. Lockheed has indicated that 0.6 fogging density can be tolerated in some films with proper film processing procedures[5]. It should be pointed out that if one knew beforehand the amount of fogging, better utilization of the yet unused film might result.

POSSIBLE SOLUTIONS

Possible solutions to the film fogging problem are:

1. Heavy shielding
2. Orbital film resupply
3. Alternatives to film
4. Development of radiation resistant films
5. Improved film processing or film storage techniques

Serious consideration should be given to developing the film on-board the spacecraft because processed film exhibits little or no sensitivity to radiation.

Since the expected film consumption rate of an orbiting observatory is on the order of a few hundred pounds a year, use of a coffin to protect the film might not be unreasonable in conjunction with film resupply once or twice per year.

Because of the penetrating nature of high energy protons, however, very large shielding thicknesses are needed to make major changes in the proton dose - see Figures 1-3. Even if the trapped Van Allen protons could be prevented from reaching the film, galactic cosmic ray protons give a 1-10 rads/year dose rate through 100 gr/cm^2-Al shields depending on the orbit chosen. Calculation of proton dose rates behind very thick shields is complicated by (1) lack of Van Allen proton spectrum data for energies greater than 300 Mev (proton range is 65 gr/cm^2-Al) and (2) production of secondary particles which can contribute to the primary protons a large fraction of the total dose rate after 30 or 40 gr/cm^2-Al. A calculation by Douglas indicates the free space galactic dose rate does not drop off to one rad/year until $10^3 gr/cm^2$-Al. Vette's model[1] for Van Allen protons with energies greater than 300 Mev indicates that behind a 65 gr/cm^2-Al shield, the trapped proton dose rate is at least a few rads/year (natural background radioactivity level at the earth's surface is about 0.2 rads/year).

Table 1 shows that many films can tolerate only 1-10 rads accumulated dose. Assuming a 4 ft^3 shielded volume in the shape of a sphere, a 163 gr/cm^2-Pb shield (equivalent to 100 gr/cm^2-Al) results in a coffin weight of about 6000 pounds and an interior dose rate somewhere on the order of a few rads/year. Due to the previously mentioned problems associated with such a calculation, the result should be viewed with great caution. The calculation does indicate that although shield weights are heavy, they are not unreasonable for a large payload capability launch vehicle.

The logistics problem and expense associated with an orbital film resupply vehicle makes such a method seem highly impractical if film replacement is required too frequently. Since the film involves relatively little weight penalty, complete film replacement should most conveniently be programmed to correspond to crew rotation.

The most reasonable solution to the film fogging problem appears to lie in the development of radiation "hardened" films and/or alternatives to film. Current efforts at MSFC (in conjunction with GSFC) seem to have developed a UV film similar to 103-0 but with a radiation resistance about 10 times greater (results still somewhat cursory at this time).[6] For any specific application, it appears that film technology can probably be pushed to obtain films an order of magnitude or so more radiation resistant than the ones now available. The eventual answer may also lie in eliminating film as much as possible in favor of high resolution T.V.

CONCLUSIONS

1. Frequent film resupply by a special logistics vehicle is uneconomical

2. Shield weights for a film coffin are large but not unreasonable.

3. Improvements in film technology should considerably reduce the sensitivity of film to radiation. In combination with moderate shielding and/or occasional resupply, the film fogging problem can probably be minimized.

4. The feasibility of using lower altitude orbits should be studied because of the lower dose rates experienced by the films.

ACKNOWLEDGEMENT

The author acknowledges the generous cooperation of A. N. deGaston of Bellcomm who is presently preparing a more extensive document on the problem of radiation film fogging.

CPWitze

1013-CPW-ek C. P. Witze

Attachments
  References
  Table I
  Figures 1-4

REFERENCES

1. Vette, J. I., Models of the Trapped Radiation Environment, NASA SP-3024 (1966).

2. Hilberg, R., private communication, October 16, 1967.

3. deGaston, A. N., "ATM Film Irradiation Problem", Bellcomm, Inc. (1967).

4. "ATM Film Radiation Damage Analysis", MSFC (1967)

5. "Radiation Characteristics of Photographic Film for use in AAP Experiments", LMSC 4.900, 226 (1967).

6. deLoach, A., private communication, October 24, 1967.

TABLE I

Film Sensitivity to Protons

Type of Film	Exposure Index (Relative Film Speed)	Proton Radiation (rads air) to Produce 0.1, 0.2, and 0.5 Fogging Densities Respectively								
		50 Mev			90 Mev			130 Mev		
103-0	250 (fast)	0.75	1.6	4.6	0.5	1.0	3.0	0.43	0.90	2.6
103-0 UV	250	0.70	1.4	3.9	0.55	1.1	3.1	0.44	0.90	2.4
SC-5	~200	0.84	1.5	4.6	0.67	1.9	5.8	0.58	1.3	4.0
Plus X, type 3401	200	1.3	2.5	6.8	0.96	1.9	4.9	0.73	1.4	3.6
SC-7	~150	1.2	2.7	12.0	0.95	2.4	10.0	0.70	1.7	7.1
Panatomic X	60	5.3	9.5	22.0	3.7	6.9	17.0	3.3	5.8	14.0
SWR	~20	11.0	22.0	57.0	7.8	16.0	42.0	7.0	14.0	37.0
SO-375	16 (slow)	17.0	30.0	64.0	14.0	24.0	52.0	13.0	22.0	47.0

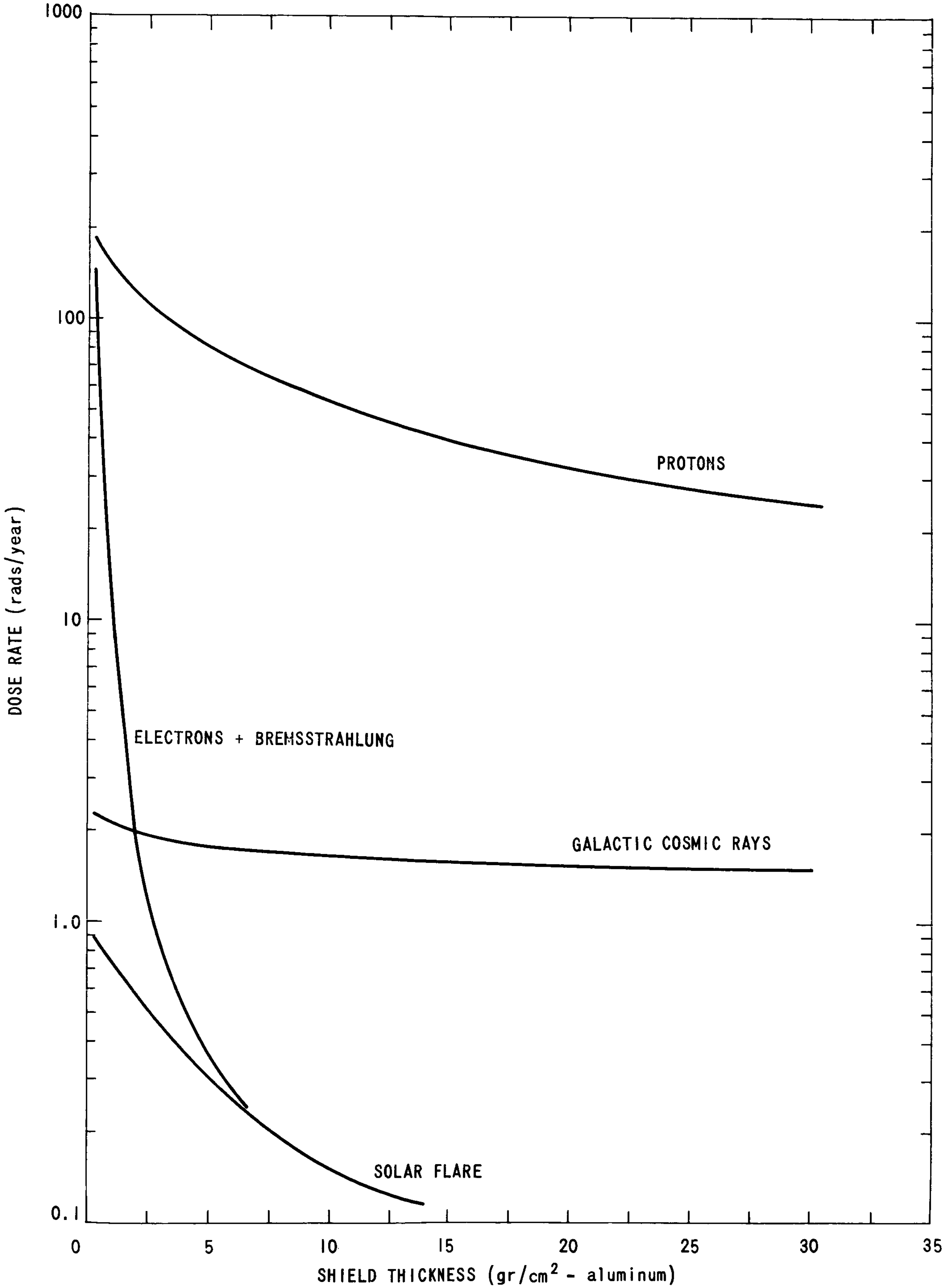

FIGURE 1 - 250 NM CIRCULAR ORBIT 30° INCLINATION

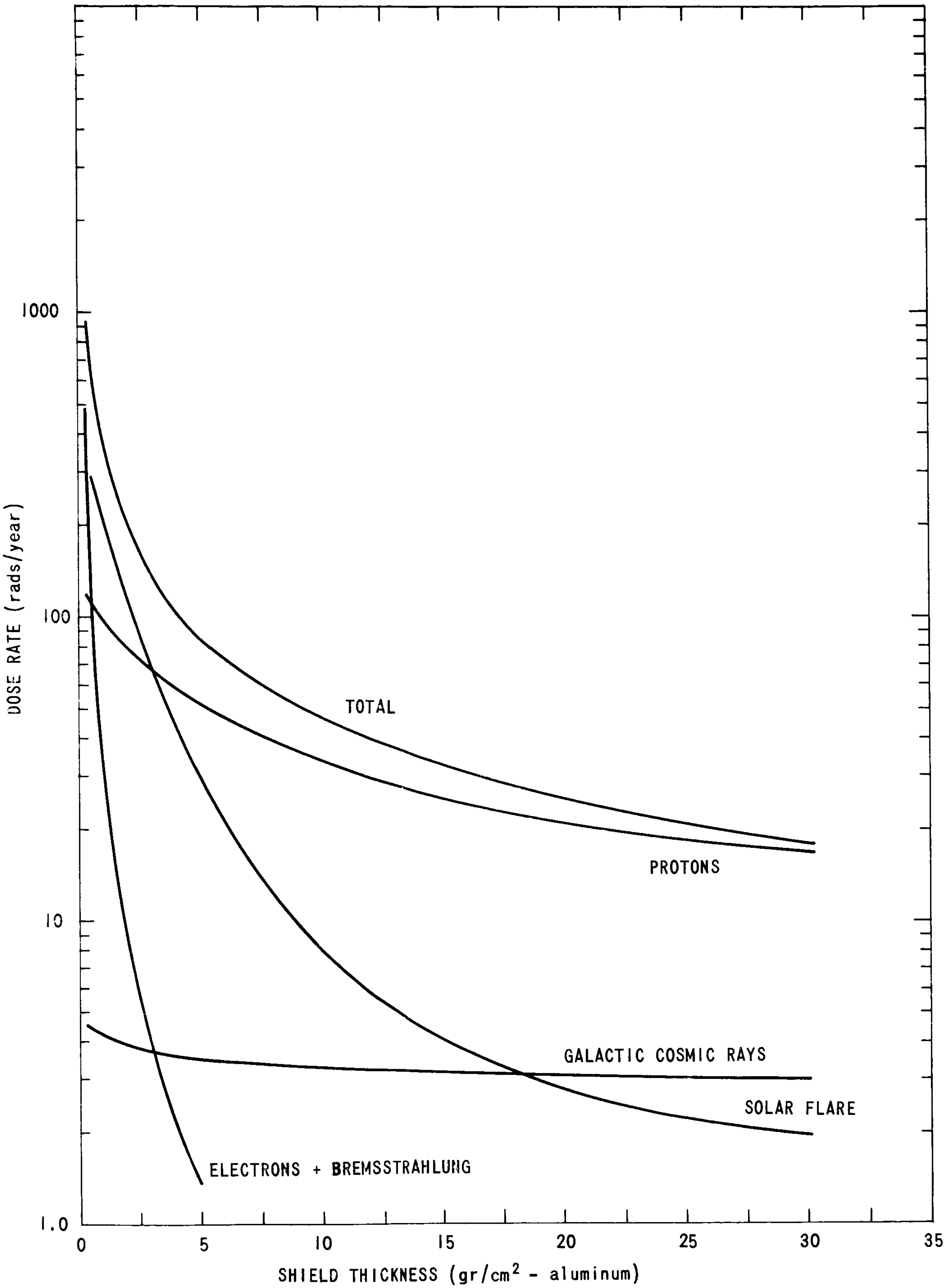

FIGURE 2 - 250 NM CIRCULAR ORBIT 90° INCLINATION

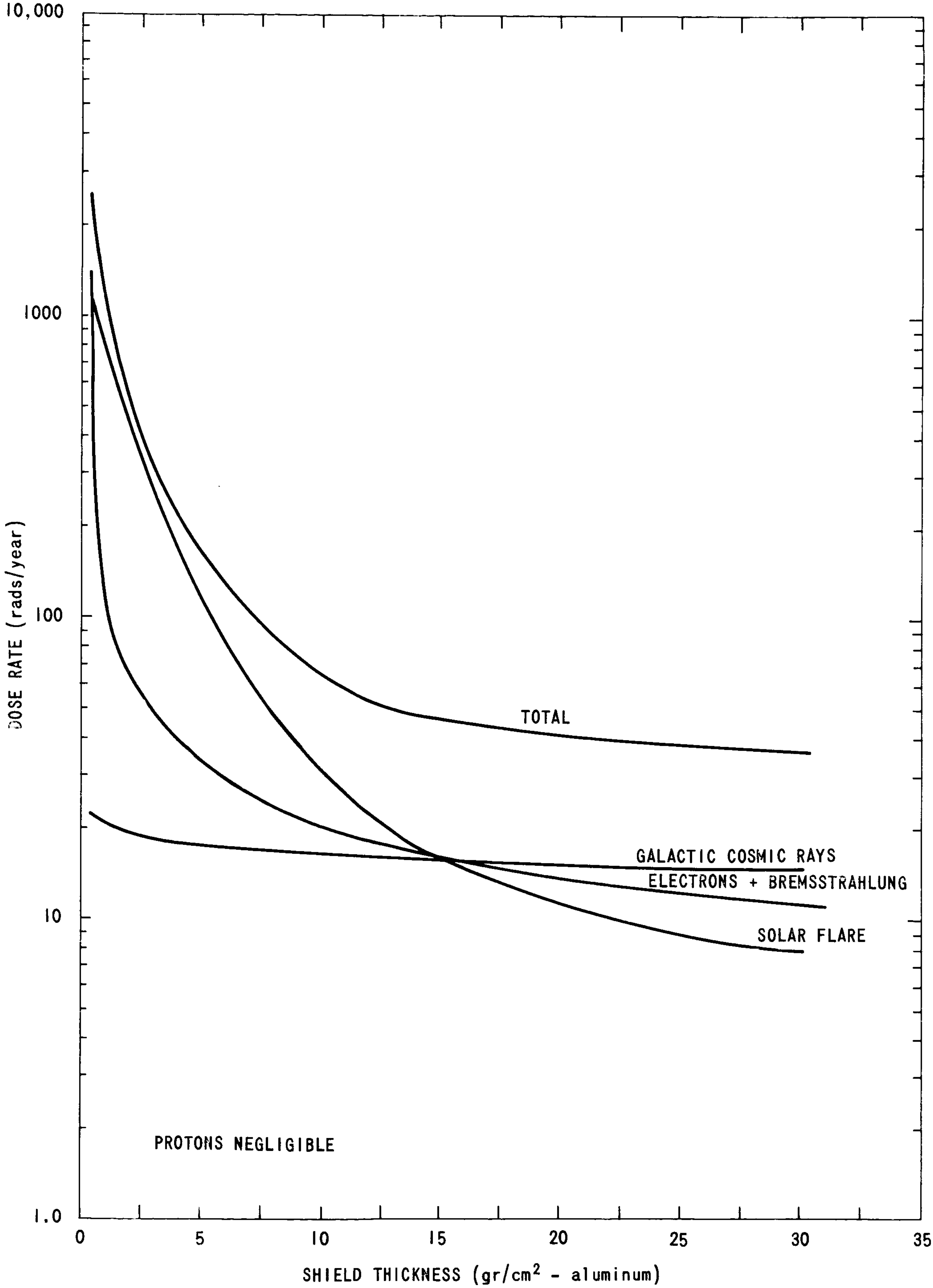

FIGURE 3 - EARTH-SYNCHRONOUS ORBIT (19323 NM) 30° INCLINATION

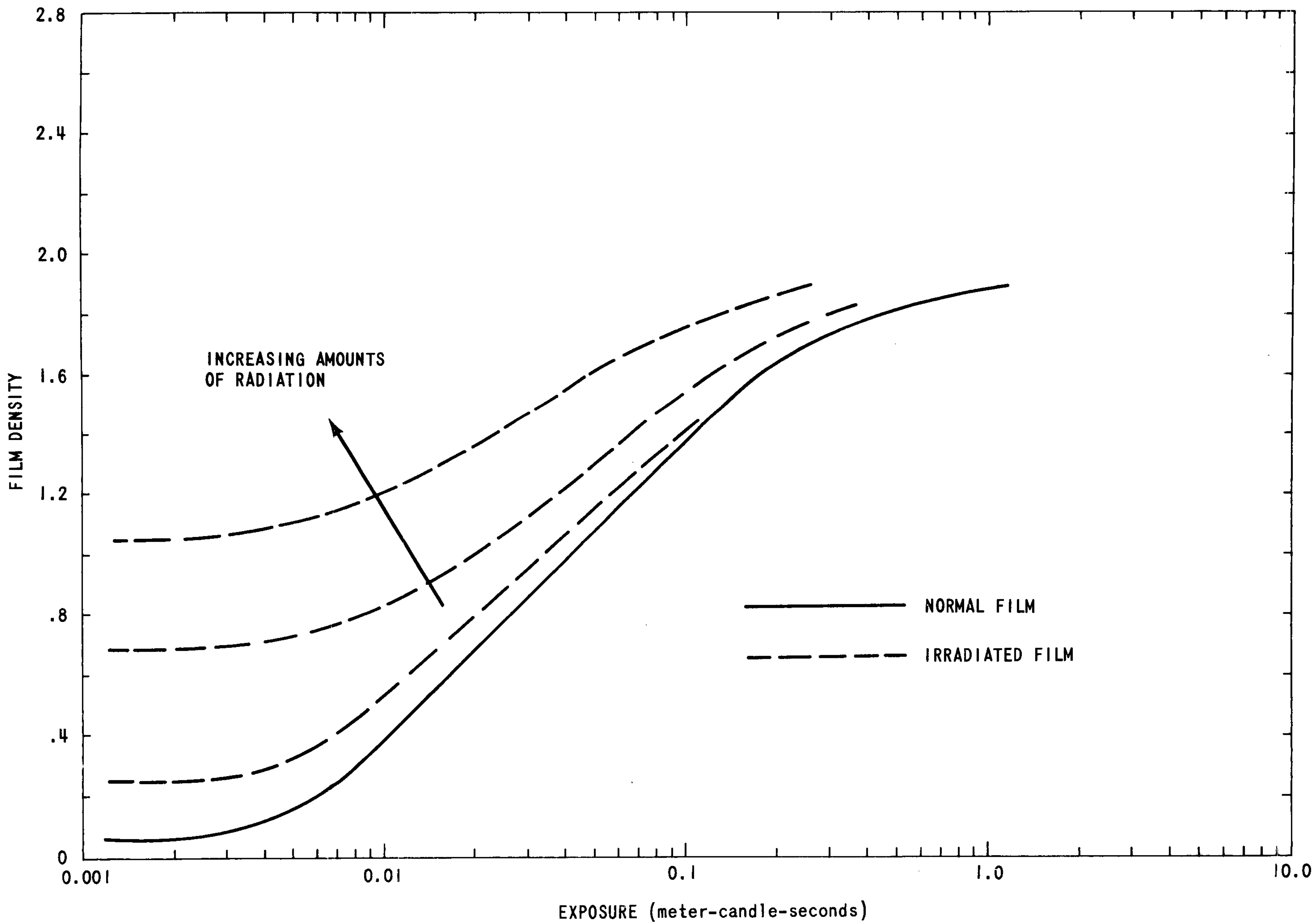

FIGURE 4 - HURTER - DRIFFIELD CURVE FOR TYPICAL FAST FILM

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